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Systematic Control for Coherently-combined High Energy Fiber Laser

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High-impact laser plasma accelerators (LPA) applications such as scientific discovery, medical radiation therapy, industrial and security screening require LPAs operating at kilohertz repetition rates or higher while today's LPAs are limited to a few Hertz repetition rates. We propose coherently combining short pulse fibers to achieve highly stabilized high energy ultrashort pulses at high repetition rates. One key challenge in reaching this objective is developing a precise feedback control system for the required pulse stability and quality. Hence, we propose to develop an integrated complex, multi-layer control system for the coherently-combined high energy fiber laser currently being built at LBNL, by using comprehensive optical system modeling, state-of-the-art digital hardware and algorithms to meet the accelerator driver stability and precision needs.

To reach the ideal high energy and high repetition rate, the following steps will be followed to develop a comprehensive controls system:
1. Develop controls for a fiber-based pulse generation and amplifier chain operating at high output power. A range of feedback control needs include thermal drifts and multi-GHz stretched-pulse programming.
2. Extend controls to multiple, parallel spectral channels and control multidimensional coherent combination. Power amplifiers will be combined into one beam.
3. Optimize overall system performance, especially compressed pulse quality. Drive accelerator experiment with resultant pulse. The output will be the highest energy from an ultrafast fiber laser.

While the temporal pulse stacking in the fiber laser combination approach has been proven to work with flat mirror stacking cavities, we propose using Herriott cells as stacking cavities to increase control stability and compactness of the system. Using Zemax modeling and an experimental setup, proof-of-concept for an improved optical stacking cavity using a Herriott cell has been established, demonstrating initial progress in optical system modeling for control system development.

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